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Nutritive Value

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Abstract

The nutritive value of a forage largely determines ruminant animal daily performance through the provision of digestible energy, crude protein (CP), minerals, and vitamins. This chapter will examine the nutritional composition of tall fescue [*Lolium arundinaceum* (Schreb.) Darbysh.] in comparison with other perennial, cool-season grasses when managed as pasture, cut and preserved as hay or silage, or stockpiled in situ for later consumption. Unlike most cool-season grasses, the relationship between the nutritive value of tall fescue and animal daily response is variable. This is attributed to the presence of the endemic endophyte *Neotyphodium coenophialum* (Morgan-Jones and Gams) Glenn, Bacon, and Hanlin, which causes the host plant–fungus symbiont to produce alkaloids that can influence negatively animal utilization of nutrients. The nutrient composition of tall fescue, however, is not altered by the presence of the endophyte. In general, the nutritive value of tall fescue is similar to that of other perennial, cool-season grasses when managed similarly. Under grazing conditions, the CP concentration, the most comprehensive index of nutritive value in the literature, of tall fescue and other cool-season grasses is greater in spring growth, declines to a low in summer,, and increases with the onset of autumn growth. Dry matter disappearance (DMD) has trends similar to those for CP, whereas fiber fractions increase in summer and decline in autumn. When stockpiling autumn growth for winter grazing, CP and DMD concentrations generally decline from early autumn to early winter, but increase again in late winter/early spring with the onset of new growth. Fiber fractions show an inverse relationship. Just as for most cool-season grasses, tall fescue CP and DMD concentrations increase and fiber fractions decrease with the supply of N fertilizer and with frequency of defoliation. Forage accumulated in summer for grazing during autumn and winter has greater CP concentrations when N application is deferred from June or July until September. When harvested and preserved as hay or silage, CP and DMD concentrations of tall fescue are similar to those of other cool-season grasses and all forages decline in both as plants mature from vegetative through the heading stage. The inconsistencies that exist between the nutritive value of tall fescue and animal daily responses are addressed, and consideration is given to the direction of future research.

The term *forage quality* often is applied to the relationship between the nutritional characteristics of forages and the production of meat, milk, fiber such as wool or hair, or work. The term sometimes is considered synonymous with nutritive value (CSSA, 1992). In practice, however, forage quality frequently is reserved for the relationship between forage characteristics and animal daily response, while nutritive value is used to describe the relationship of plant

 Tall Fescue for the Twenty-first Century. H.A. Fribourg, D.B. Hannaway, and C.P. West (ed.) Agronomy Monograph 53.

chemical composition to nutrient digestibility and absorption (i.e., utilization) without necessarily taking into account factors related to intake and antiquality factors. Both of the latter must be considered, however, to extend the relationship to animal performance. This chapter addresses the anatomical and chemical constituents of tall fescue that relate to animal nutrition, narrowly defined as nutritive value. Other aspects of forage quality relating to intake and antiquality traits are addressed in sections dealing with animal responses (see Chapters 16 [Waller, 2009] and 17 [Cross, 2009], this publication). The in vitro bioassay for estimating apparent dry matter digestion will be referred to as *dry matter disappearance* (DMD) or *in vitro true dry matter disappearance* (TDD) and will be included with the nutritive value measurements.

The endophyte in tall fescue (Bacon and Siegel, 1988), *Neotyphodium coenophialum*, produces ergot alkaloids (see Chapters 13 [Bush and Fannin, 2009] and 14 [Christensen and Voisey, 2009], this publication) that, when present in sufficient concentration in the forage, causes toxicosis in ruminants (Hill et al., 1994) and horses. These effects have complicated the interpretation of literature regarding the value of tall fescue as a livestock feed. Generally, the presence of toxins from the endophyte–grass symbiont is not reflected in estimates of the nutritive value determined on the forage (Bush and Burrus, 1988; Collins, 1991; Fritz and Collins, 1991; Turner et al., 1993), but can alter significantly the forage quality through negative influences on the physiology of the animal and, hence, on animal daily forage intake and rates of increase in body mass (see Chapter 12, Strickland et al., 2009, this publication). The presence of toxins from the endophyte–host plant symbiont in tall fescue can depress animal growth and health substantially under a wide range of plant, animal, and climatic conditions (Stuedemann and Hoveland, 1988). Effects range from suppressed animal daily response in ruminants to aborted fetuses in horses and, in severe cases, loss of mature animals (see Chapter 18, Craig, 2009, this publication). The recent introduction of endophytes (see Chapter 20, Bouton, 2009, this publication) that do not produce ergot alkaloids in tall fescue (Bouton et al., 2002) or modification of the endophyte presently found in tall fescue to reduce ergot alkaloid production (Hill et al., 2002) have shown potential to reduce or eliminate the impact of the toxicosis.

The development and release of modified or new cultivars (see Chapter 19, Hopkins et al., 2009, this publication) will require reevaluation and new documentation of the potential of tall fescue as a forage through a series of critical plant and animal evaluation trials. This chapter examines the nutritive value of tall fescue when grazed as pasture or clipped to simulate grazing, when accumulated as a stockpiled forage for late autumn and winter utilization, and when harvested and stored as hay or silage. A tabular format was selected for much of the data presentation to facilitate future additions as new data become available.

Anatomical Considerations

The anatomy of forage plants impacts forage nutritive value through the physical arrangement, chemical composition, and proportional mass of each tissue type (Grabber et al., 1992). Cool-season grasses possess leaf anatomy that is characteristic of the C_3 photosynthetic mechanism, whereas warm-season grasses generally possess leaf anatomy typical of the C_4 mechanism (Volenec and Nelson, 2007). Leaves with C_3 anatomy have lower cell wall concentrations and a greater proportion of highly digestible cell solubles than leaves of C_4 plants (Goering and Van Soest, 1970; Van Soest and Robertson, 1980). Cell wall concentrations in C_3 grasses range between 550 and 700 g/kg, whereas they are 600 to 800 g/kg in C_4 grasses. The cell walls of C_3 plants also are degraded more rapidly in the rumen (Hanna et al., 1973; Akin and Burdick, 1975). For example, leaf tissue of tall fescue after 6, 12, 24, 48, and 72 h of fermentation had DM disappearances of 175, 234, 262, 482, and 449 g/kg, respectively (Akin et al., 1973). This compared with disappearances of 5, 96, 88, 183, and 314 g/kg, respectively, for 'Coastal' bermudagrass [*Cynodon dactylon* (L.) Pers.] leaves for the same durations (Akin et al., 1973).

Analyzing forages for their proportions of rapidly vs. slowly degradable tissue types helps explain forage quality differences among species in addition to chemical composition differences. Cool-season C_3 grasses have a lower proportion of leaf cross-sectional area composed of slowly rumen-degradable tissue types than C_4 grasses and a correspondingly greater proportion of rapidly rumen-degradable tissue types (Akin et al., 1973, 1975; Buxton, 1990; Fisher et al., 1989). The proportional area of rapidly degraded tissue of the C_4 grasses bermudagrass, bahiagrass (*Paspalum notatum* Flüggé), dallisgrass (*Paspalum dilatatum* Poir.), and pangolagrass (*Digitaria eriantha* Steud.), averaged 27 to 55% when compared with 56 to 66% for the C_3 grasses smooth bromegrass (*Bromus inermis* Leyss.), orchardgrass (*Dactylis glomerata* L.), timothy (*Phleum pratense* L.), Kentucky bluegrass (*Poa pratensis* L.), and tall fescue (Akin and Burdick, 1975). Slowly degraded tissue area averaged 36 to 56% for the C_4 grasses but only 22 to 31% for the C_3 grasses. Grouping tissues relative to rate of in vitro degradation in rumen fluid showed that 39% of C_4 grass tissues were rapidly degradable, 50% were slowly degradable, and 11% were not degradable. This compares with values of 60, 26, and 15%, respectively, for C_3 grass tissues, indicating a physical basis for the greater disappearance of the C_3 grasses (Akin et al., 1975).

Within the cool-season grasses, cross-sectional areas of leaf blade tissues were compared among tall fescue, orchardgrass, bromegrass, and Kentucky bluegrass (Akin et al., 1975). Tall fescue leaf blades averaged 11% vascular tissue (slow degradability) compared with 22% for orchardgrass and 20% for bromegrass. Mesophyll tissue (fast degradability) averaged 65% for tall fescue compared with 54% for orchardgrass and 53% for bromegrass. All measurements for Kentucky bluegrass were similar to those for tall fescue (Akin et al., 1975). Furthermore, tissue variation in tall fescue was of sufficient magnitude to permit alteration of certain cell arrangements through breeding methods (Hanna et al., 1973; Soh et al., 1984). These data indicate that tall fescue has the potential to have nutritive value that is comparable to, if not greater than, those of orchardgrass, smooth bromegrass, and Kentucky bluegrass.

Intrinsic differences in plant tissues among forage species are altered differentially by tissue maturity (Buxton and Russell, 1988) and environmental stresses (Kephart and Buxton, 1993; Allinson, 1971). These facets become integrated in the diet of animals, as ruminants selectively ingest green leafy tissue (Hodgson, 1981) one bite at a time in grazing bouts during each 24 h (Ungar, 1998; Burns and Sollenberger, 2002). Because tall fescue possesses characteristic C_3 anatomy, its nutritive value and ultimate quality will be discussed relative to those of other C_3 perennial grasses.

Endophyte Relationships

The occurrence of the toxic endophyte in tall fescue is frequently associated with reduced nutritive value. However, the nutritive value of tall fescue was not altered by the presence of the toxic endophyte regardless of method of preservation, cultivar used, maturity at harvest, or location where grown (Table 11–1). In addition, no difference in CP concentrations resulted between endophyte free (E–) and endophyte infected (E+) tall fescue over a range of concentrations from about 100 to 172 g/kg. Moreover, when comparing rate of DMD between E– and E+ tall fescues [mean of 'Kentucky 31' (KY-31) and 'Kenhy'] the disappearance rate constants were both 0.056/h, with similar respective lag times of 10.0 and 9.9 h and similar NDF disappearance averaging 671 g/kg after 72 h (Fritz and Collins, 1991). The recent incorporation of novel endophytes into 'Jesup' tall fescue (marketed as MaxQ; trademarked by Pennington Seed Co., Madison, GA, USA) and into 'HiMag' (cultivar ArkPlus) has been evaluated in comparison with Jesup or HiMag that was E– or contained the E+ wild endophyte.[1] Whether managed as pasture, hay, or stockpile, the differences in DMD, CP, and fiber fractions for Jesup (Table 11–1) generally were similar, and differences among the HiMag types when stockpiled also were similar for CP and fiber fractions. Only means for the three HiMag types were presented, averaging 133 g/kg for CP, 549 g/kg for NDF, and 311 g/kg for ADF (Kallenbach et al., 2003). Consequently, the presence or absence of the toxic or novel endophytes had little influence on estimates of nutritive value, rendering the endophyte status a moot point in that regard. Endophyte status, however, is involved in the apparent paradox between nutritive value and animal response, which is addressed below.

Management Strategies

Management options are extremely flexible with tall fescue (see Chapters 6 [Roberts et al., 2009] and 7 [Milne, 2009], this publication) with possibilities for utilization as pasture for late winter and spring, late spring, early summer and autumn, as well as early-winter grazing, depending on latitude, altitude, ambient temperatures, and moisture availability (see Chapter 3, Hannaway et al., 2009). Tall fescue also can be harvested and stored as hay or silage. In many regions, tall fescue can be accumulated from late summer growth as a stockpile (i.e., accumulated forage) used for subsequent fall and winter grazing. Because these different management strategies result in tall fescue forage utilized at different maturities, the nutritive value of the forage can vary appreciably. Consequently, the nutritive value of the forage for each management strategy will be addressed separately. It should be noted at this point that although CP is generally the nutritive value estimate most prevalent in the literature, it should not be inferred that its concentrations are a limiting factor in animal production systems.

Pasture

Crude Protein

When managed as pasture, the CP concentration in tall fescue generally was similar to or less than that of similarly managed orchardgrass, Kentucky bluegrass, or reed canarygrass (*Phalaris arundinacea* L.) (Item A, Table 11–2). In most

[1] The use of tradenames does not imply endorsement by USDA-ARS or by the North Carolina ARS of the products named or criticism of similar ones mentioned.

Table 11–1. The nutritive value of tall fescue with or without endophyte.

			Management			Nutritive value‡								Volatile fatty acids			
Location†	Fescue cultivar	Endophyte	Maturity	Condition	DMD	CP	NDF	ADF	HEMI	CELL	Lignin	CHO	pH	Acetic	Lactic	Butyric	References
					g/kg									g/kg			
KY	KY-31	Low		Forage		162	654	321									Bush and Burrus, 1988
		High				172	643	317									
		Low		Seed		147	418	321									
		High				155	406	317									
GA	KY-31	No		Green-								138					Hill et al., 1990
		Yes		house								136					
KY	Kenhy	0%		0 N	634	117	645										Collins, 1991
				75 N	659	132	628										
				150 N	657	140	642										
		97%		0 N	644	118	637										
				75 N	651	134	640										
				150 N	661	139	620										
KY	KY-31	0%				122	636		323	283	32						Fritz and Collins, 1991
	Kenhy	76%				119	642		328	291	32						
AK	KY-31	No	Boot	Silage	565	163	568	324					4.07	27	70	1.2	Turner et al., 1993
		Yes			592	169	563	323					4.06	36	59	1.5	
		No	Mature	Silage	443	94	693	415					5.21	25	52	2.8	
		Yes			453	100	703	420					5.13	20	43	2.9	
UT	KY-31	No			862§	163	468										Asay et al., 2002
		Yes			859§	165	472										
KS	KY-31	0%		Hay		66	725	399			42						Humphrey et al., 2002
		70%				81	727	401			41						
GA	Jesup	0	Spring	Pasture	728	200	477	266									Parish et al., 2003
	Jesup	>59%	(Mar.–June)		682	204	503	293									
	MaxQ	>59%			710	202	482	276									
	Jesup	0	Fall	Pasture	638	162	572	301									
	Jesup	>59%	(Sept.–Dec.)		644	165	602	309									
	MaxQ	>59%			626	160	584	314									

Table continued.

Table 11–1. Continued.

Location†	Fescue cultivar	Endophyte	Management		Nutritive value‡									Volatile fatty acids			References
			Maturity	Condition	DMD	CP	NDF	ADF	HEMI	CELL	Lignin	CHO	pH	Acetic	Lactic	Butyric	
					g/kg									g/kg			
NC	Jesup	5%	April	Hay	806§	164	593	290	303	255	27						Burns and Fisher, 2006
	Jesup	94%			793	163	599	292	307	257	28						
	MaxQ	95%			809	167	602	291	311	257	26						
	Jesup	5%	June		732	146	639	322	318	282	32						
	Jesup	94%			713	131	651	322	328	286	32						
	MaxQ	95%			730	135	645	315	329	279	29						
NC	Jesup	5%	Veg	Stk	736§	127	553	286	267	253	30	177					Burns et al., 2006
	Jesup	94%			730	126	553	286	266	252	30	174					
	MaxQ	95%			731	129	552	288	265	254	30	177					

† State where data were collected.

‡ DMD = dry matter disappearance; CP = crude protein; NDF = neutral detergent fiber; ADF = acid detergent fiber; HEMI = hemicellulose; CELL = cellulose; CHO = Soluble Carbohydrates.

§ In vitro true dry matter disappearance.

Table 11–2. Crude protein (CP) concentrations in tall fescue compared with other cool-season grasses when managed as pasture and altered by management practices.

Location†	Forage‡	Fescue cultivar	Management Season	General	Fert.	CP	Reference
					kg/ha	g/kg	
A. Tall fescue vs. other cool-season grasses							
KY	TF	KY-31		Clipped		213	Lassiter et al., 1956
	OG			every		226	
	SB			2 wk		256	
	BG					192	
WA	TF	Alta	21 Apr.			141	Austenson, 1963
			9 May			99	
			31 May			89	
			21 June			69	
			10 July			51	
	OG		21 Apr.			163	
			9 May			98	
			31 May			76	
			21 June			58	
			10 July			47	
	RG		21 Apr.			142	
			9 May			102	
			31 May			95	
			21 June			73	
			10 July			67	
IA	TF	KY-31	June			77	Bryan et al., 1970
			July			99	
			Oct.			186	
			Nov.			148	
	RC		June			114	
			July			90	
			Oct.			226	
			Nov.			158	
WV	TF	Kenhy	Spring			169	Barker et al., 1988
			Fall			75	
	OG		Spring			194	
			Fall			88	
	TF	Alta		Mixed		91	
	BG			with		91	
	OG			alfalfa		107	
WV	TF	Kenhy	Spring			152	Prigge et al., 1999
			Fall			124	
	OG		Spring			166	
			Fall			129	
B. Among tall fescue cultivars							
KY	TF	KY-31	Summer			219	Buckner et al., 1967
			Fall			225	
	TF	Kenwell	Summer			231	
			Fall			220	
GA	TF	KY-31		Without		221	Belesky et al., 1982
		Kenhy		irrigation		197	
		Fawn				224	
	TF	KY-31		With		181	
		Kenhy		irrigation		181	
		Fawn				204	

Table continued.

Table 11–2. Continued.

Location†	Forage‡	Fescue cultivar	Management Season	General	Fert.	CP	Reference
					kg/ha	g/kg	
PA	TF	KY-31				201	Vecellio et al., 1995
		Festorina				204	
		Johnstone				201	
		Roa				208	
C. Nitrogen fertilization							
WV	TF	KY-31	May	Veg.	0 N	170	Reid et al., 1967
					56 N	232	
					504 N	306	
				Boot	0 N	129	
					56 N	142	
					504 N	197	
			June	Headed	0 N	89	
					56 N	119	
					504 N	162	
			Aug.	Regrowth	0 N	99	
					56 N	122	
					504 N	190	
TN	TF	KY-31	Spring		0 N	136	Fribourg and Loveland, 1978a
					50 N	171	
					100 N	176	
					150 N	176	
					200 N	203	
					250 N	210	
			Summer		0 N	133	
					50 N	134	
					100 N	133	
					150 N	170	
					200 N	178	
					250 N	176	
			Fall		0 N	114	
					50 N	125	
					100 N	196	
					150 N	176	
					200 N	202	
					250 N	213	
IA	TF	KY-31			0 N	81	Mitchell et al., 1985
					112 N	95	
D. Defoliation intensity							
MO	TF	KY-31	Spring	2 cut		98	Ocumpaugh and Matches, 1977
			Summer	3 cut		120	
				5 cut		164	
NC	TF	KY-31	Spring	8–5§		197	Chamblee and Isley, 2002
				10–5		198	
				15–5		189	
				11–9		220	
				15–9		203	
			Fall	8–5		241	
				10–5		241	
				15–5		196	
				11–9		229	
				15–9		220	

Table continued.

Table 11–2. Continued.

Location†	Forage‡	Fescue cultivar	Management			CP	Reference
			Season	General	Fert.		
					kg/ha	g/kg	
NC	TF	KY-31	Spring	10–5		183	Burns and Chamblee, 2002
				15–5		179	
				11–9		185	
			Summer	10–5		152	
				15–5		137	
				11–9		181	

† State where data were collected.

‡ TF = tall fescue; OG = orchardgrass; BG = Kentucky bluegrass; RC = reed canarygrass; RG = perennial ryegrass.

§ 8–5 is read as each time the canopy attained 8 cm it was defoliated to a 5-cm stubble.

cases CP concentrations were adequate to support acceptable animal daily performance (National Research Council, 1996). The noted exceptions were in the summer and autumn, when CP concentrations can drop below 100 g/kg.

The inclusion of tall fescue, Kentucky bluegrass, or orchardgrass in a mixture with alfalfa (*Medicago sativa* L.) (Item A, Table 11–2) resulted in all three grasses having low CP, averaging 91, 107, and 107 g/kg, respectively. The use of irrigation on tall fescue generally depressed CP concentration regardless of cultivar (Item B, Table 11–2).

Nitrogen application increased the CP concentration whether forage was harvested in the vegetative, boot, or headed stages of maturity—a trend that carried over to the summer regrowth (Item C, Table 11–2). Crude protein concentrations in the spring generally were greater than those in the summer.

Defoliation intensity altered CP, with greatest concentrations occurring from regimes with more frequent cuttings (Item D, Table 11–2). Crude protein concentrations decreased during summer, but could be increased by raising the stubble height. Although not shown in Table 11–2, CP concentration of tall fescue harvested to an 11- to 9-cm stubble declined to 133 g/kg in late May (spring) of Year 1 and 135 g/kg in July of Year 2, but in Year 3 concentrations remained above the August low CP concentration of 155 g/kg. The respective number of cuts per year totaled 14, 15, and 22 (Burns et al., 2002). These year-to-year differences, associated mainly with rainfall and temperature, can greatly influence tall fescue composition during stress periods in summer.

Dry Matter Disappearance and Fiber Fractions

The DMD of tall fescue was, with few exceptions, greater than that obtained from orchardgrass in both summer and autumn (Item A, Table 11–3). This difference was reflected also in reduced NDF and ADF concentrations. Although season altered DMD, with summer disappearance the least, little difference was noted among tall fescue cultivars (Item B, Table 11–3). This was observed also for NDF and ADF where data were available. Regardless of stage of maturity and subsequent regrowth, N fertilization generally increased DMD and decreased NDF and ADF concentrations (Item C, Table 11–3). In the winter season, forage cut to a 5-cm stubble generally had greater DMD in the green tissue, and DMD

Table 11–3. Dry matter disappearance (DMD), fiber fractions, and soluble carbohydrate (CHO) concentrations in tall fescue when managed as pasture and compared with other cool-season grasses.

Location†	Forage‡	Fescue cultivar	Management: Season/month	Management: General	Management: Fert.	DMD	NDF§	ADF§	CHO	References
					kg/ha	g/kg				
A. Tall fescue vs. other cool-season grasses										
IN	TF	KY-31		0600 h					57	Holt and Hilst, 1969
				1200 h					75	
				1800 h					89	
	KG			0600 h					54	
				1200 h					65	
				1800 h					75	
	SB			0600 h					48	
				1200 h					59	
				1800 h					70	
IA	TF	KY-31		June		555				Bryan et al., 1970
				July		626				
				Oct.		626				
				Nov.		661				
	RC			June		633				
				July		541				
				Oct.		607				
				Nov.		579				
WI	TF	KY-31	June						134	Smith, 1972
	OG								121	
	RC								75	
	KG								127	
WV	TF	Kenhy	Spring			660	564	302		Barker et al., 1988
			Fall			577	615	336		
	OG		Spring			640	582	295		
			Fall			467	644	379		
	TF	Kenhy	Spring			663		322		Prigge et al., 1999
			Fall			629		370		

Location†	Forage‡	Fescue cultivar	Management: Season/month	Management: General	Management: Fert.	DMD	NDF§	ADF§	CHO	References
					kg/ha	g/kg				
	OG		Spring			665		310		
			Fall			609		370		
B. Among tall fescue cultivars										
KY	TF	KY-31	Summer			649			78	Buckner et al., 1967
			Fall			773			170	
	TF	Kenwell	Summer			660			80	
			Fall			769			176	
KY	TF	KY-31	Summer			689		250		Buckner et al., 1979
		Kenhy	Summer			725		258		
PA	TF	KY-31				701	465	258		Vecellio et al., 1995
		Festorina				696	476	266		
		Johnston				710	464	256		
		Roa				706	456	248		
		Mean of all four cultivars	Spring			700	483	267		
			Summer			690	470	263		
			Fall			719	444	242		
C. Nitrogen fertilization										
WV	TF	KY-31	May	Veg.	0 N	761	509	288	104	Reid et al., 1967
					56 N	796	489	283	70	
					504 N	822	457	251	100	
			May	Boot	0 N	711	597	340	118	
					56 N	741	592	349	110	
					504 N	780	586	330	106	
			June	Headed	0 N	675	652	381	126	
					56 N	696	626	371	94	
					504 N	716	613	355	95	
			Aug.	Regrowth	0 N	564	651	383	99	
					56 N	624	618	356	96	
					504 N	729	609	75	329	

Table continued.

Table 11–3. Continued.

Location†	Forage‡	Fescue cultivar	Management: Season/month	Management: General	Management: Fert.	DMD	NDF§	ADF§	CHO	References
					kg/ha	g/kg				
GA	TF	KY-31	Winter	5 cm-G	56 N	746				Beaty et al., 1978
				5 cm-D		437				
				5 cm-G	224 N	775				
				5 cm-D		419				
				10 cm-G	56 N	731				
				10 cm-D		418				
				10 cm-G	224 N	713				
				10 cm-D		438				
TN	TF	KY-31	Spring		0 N	640				Fribourg and Loveland, 1978a
					100 N	674				
					150 N	658				
					200 N	702				
			Summer		0 N	558				
					100 N	550				
					150 N	581				
					200 N	576				
			Fall		0 N	541				
					50 N	640				
					100 N	668				
					150 N	640				
					200 N	662				
D. Defoliation intensity										
GA	TF	KY-31	Spring	0–2.5 cm		310				Burns, 1970
			(Vert. Layers)	2.5–5.0 cm		300				
				5.0–7.5 cm		420				
				7.5–15.0 cm		600				
MO	TF	KY-31	Spring	2 cut		483				Ocumpaugh and Matches, 1977
			Summer	3 cut		543				
				5 cut		670				

Location†	Forage‡	Fescue cultivar	Management: Season/month	Management: General	Management: Fert.	DMD	NDF§	ADF§	CHO	References
					kg/ha	g/kg				
NC	TF	KY-31	Spring	10–5		700	510	260	85	Burns and Chamblee, 2002
				15–5		700	520	275	110	
				11–9		699	455	254	100	
			Summer	10–5		636	490	275	113	
				15–5		546	550	310	100	
				11–9		678	475	275	120	

† State where data were collected.

‡ TF = tall fescue; RC = reed canarygrass; BG = Kentucky bluegrass; SB = smooth bromegrass.

§ NDF = neutral detergent fiber; ADF = acid detergent fiber.

increased at higher N rates. This is in contrast to forage cut at 10 cm where the green tissue was similar in DMD among N rates.

Defoliation intensity showed little effect in the spring when forage cut from a 10-cm canopy height to a 5-cm stubble (10–5) was compared with forage cut from 15 cm to a 5-cm stubble (15–5) or from 11 cm to a 9-cm stubble (Item D, Table 11–3). In summer, however, cutting 15–5 decreased DMD when compared to 10–5. In contrast, raising the stubble to 9 cm increased DMD. This is consistent with the increase in DMD normally found higher in the plant canopy. Raising the stubble from 5 to 9 cm also reduced NDF and ADF, indicating that raising the grazing height during the summer stress period would increase utilization of forage with greater nutritive value.

Soluble Carbohydrates

The diurnal change in soluble carbohydrate concentrations shows that tall fescue reached higher concentrations of soluble carbohydrates between 0600 h and 1800 h than either Kentucky bluegrass or bromegrass (Item A, Table 11–3), although similar trends occurred for all three forages. Greater soluble carbohydrate concentrations in afternoon-harvested than in morning-harvested forages improved nutritive value (Holt and Hilst, 1969; Lechtenburg et al., 1972; Burns et al., 2001).

Harvested and Stored as Hay or Silage

Crude Protein

The concentration of CP in tall fescue was generally similar to that of orchardgrass, although in a few cases orchardgrass CP was greater (Item A, Table 11–4). When compared in the same study, reed canarygrass, smooth bromegrass, and Kentucky bluegrass generally had greater CP concentrations than tall fescue, regardless of cutting frequency. Management strategies such as frequency of cut, P or N fertilization, and season of cut altered CP concentrations, but the rank among cool-season grass species was retained. With few exceptions, when CP concentrations in tall fescue were low, the CP of other cool-season grasses were also low and, in general, reflected the N status of a particular study.

Differences in CP concentrations among tall fescue cultivars were evident, with Kenhy and 'Johnstone' generally greater in CP and 'Stargrazer' the lowest among the cultivars tested (Item B, Table 11–4). Within any of these comparisons, the differences in CP among cultivars were small and, under most conditions, unlikely to be reflected in animal performance. Increasing N applications also increased CP concentrations of the forage (Item C, Table 11–4), as did the application of a growth regulator in June (Item D, Table 11–4). The application of supplemental water, on the other hand, generally reduced CP concentrations.

Dry Matter Disappearance and Fiber Fractions

Tall fescue and orchardgrass had similar DMD for a range of maturities, whereas reed canarygrass, smooth bromegrass, and Kentucky bluegrass had less DMD when harvested infrequently (more mature forage), with differences among species very small when harvested frequently (Item A, Table 11–5). In the latter case, plants remained vegetative, thereby reducing the expression of variation in DMD as a result of morphological differences—variable proportions of leaves as compared to stems. In the numerous comparisons between tall fescue

Table 11–4. Crude protein concentrations in tall fescue compared with other cool-season grasses when harvested for hay or silage.

Location†	Forage‡	Fescue cultivar	Management			Crude protein	References
			Season	General	Fert.		
					kg/ha	g/kg	
A. Tall fescue vs. other cool-season grasses							
WA	TF	Alta		Mixed		77	Comstock and Low, 1948
	SB			with		70	
	OG			alfalfa		87	
PA	TF	Alta				110	Phillips et al., 1954
	OG					89	
	RC					114	
	SB					101	
	BG					123	
MD	TF	KY-31			0 N	114	
					90 N	124	
					180 N	155	Wagner, 1954
	OG				0 N	100	
					90 N	117	
					180 N	147	
	BG				0 N	128	
					90 N	151	
					180 N	159	
NJ	TF	Alta				130	Duell, 1960
	OG					134	
	RC					163	
	SB					157	
	BG					138	
WA	TF	Alta		Anthesis		68	Sosulski and Patterson, 1961
	SB					79	
	OG					67	
KY	TF	KY-31	Spring		50 N	211	Hojjati et al., 1973
					100 N	283	
					150 N	303	
					200 N	325	
	BG				50 N	270	
					100 N	306	
					150 N	321	
					200 N	328	
MN	TF	KY-31		2 cuts		129	Marten and Hovin, 1980
	OG					127	
	RC					132	
	SB					140	
	TF	KY-31		3 cuts		138	
	OG					148	
	RC					169	
	SB					166	
	TF	KY-31		4 cuts		155	
	OG					165	
	RC					210	
	SB					202	
VA	TF	KY-31	Summer			94	Rayburn et al., 1980
	OG					136	
TX	TF	Fawn	Spring	Irrigated		140	Eck et al., 1981
	OG		Summer			157	
PA	TF	KY-31	Summer		Low P	144	Morris et al., 1982

Table continued.

Table 11–4. Continued.

Location†	Forage‡	Fescue cultivar	Management Season	General	Fert.	Crude protein	References
					kg/ha	g/kg	
					High P	127	
	OG				Low P	160	
					High P	154	
MN	TF	KY-31	All			139	Sheaffer and Marten, 1986
	RC					145	
	SB					147	
	BG					155	
	OG					149	
TN	TF	Johnstone				181	Baxter et al., 1986
		Kenhy				166	
	OG					170	
WV	TF	Kenhy	Spring			98	Barker et al., 1988
	OG					91	
	TF	Kenhy	Fall			93	
	OG					101	
WV	TF	Kenhy	Spring			88	Prigge et al., 1999
	OG					87	
	TF	Kenhy	Fall			137	
	OG					143	
B. Among tall fescue cultivars							
KY	TF	KY-31		Soilage		128	Ghorbani et al., 1991
	TF	Kenhy				133	
	TF	Johnstone				141	
ID	TF	KY-31	July			90	Burns et al., 2001
		Kenhy				94	
		HiMag				89	
		Barcel				92	
		Stargraze				82	
		MO-96				86	
		Mozark				89	
		KY-31	Aug.			227	
		Kenhy				230	
		HiMag				227	
		Barcel				238	
		Stargraze				229	
		MO-96				232	
		Mozark				228	
C. Nitrogen fertilization							
WV	TF	KY-31	Initial Growth		0 N	127	Reid and Jung, 1965
					56 N	195	
					168 N	237	
					504 N	238	
			Regrowth		0 N	98	
					56 N	139	
					168 N	179	
					504 N	186	
KY	TF	KY-31	Spring		50 N	211	Hojjati et al., 1973
					100 N	283	
					150 N	303	
					200 N	325	
TX	TF	KY-31	Spring Summer		0 N	108	Eck et al., 1981
					65 N	126	
					336 N	153	

Table continued.

Table 11–4. Continued.

Location†	Forage‡	Fescue cultivar	Management			Crude protein	References
			Season	General	Fert.		
					kg/ha	g/kg	
					504 N	171	
					672 N	185	
D. Other managements							
GA	TF	KY-31		Dry		167	Craigmiles and Crowder, 1960
				Irrigated		145	
GA	TF	KY-31		Cool		128	Smith, 1977
				Hot		122	
TX	TF	Fawn	Spring	50 cm Irr.		156	Eck et al., 1981
			Summer	100 cm Irr.		139	
KY	TF	KY-31	21 Apr.	31 May		111	Robb et al., 1982
			−GR§	15 July		93	
				18 Aug.		104	
			+GR	31 May		95	
				15 July		104	
				18 Aug.		106	
			6 June	14 July		116	
			−GR	18 Aug.		104	
			+GR	14 July		134	
				18 Aug.		118	
TN	TF	KY-31	Apr.	9 July		–	Reynolds et al., 1993
			−GR			109	
			+GR			119	
AK	TF	KY-31	Boot	Fresh		169	Turner et al., 1993
			Mature	Fresh		90	
				Silage		140	

† State where data were collected.

‡ TF = tall fescue; OG = orchardgrass; RC = reed canarygrass; SB = smooth bromegrass; BG = Kentucky blue grass.

§ Growth regulator.

and orchardgrass, tall fescue generally is either greater or similar to orchardgrass in DMD. Noted exceptions are from irrigated production, which showed greater DMD for orchardgrass (615 vs. 566 g/kg). When available, NDF and ADF concentrations generally were related negatively to DMD, with greater fiber concentrations associated with reduced DMD.

The differences among tall fescue cultivars in DMD generally were small and ranged only from 599 to 604 g/kg in a study comparing KY-31, Kenhy, and Johnstone. Differences in TDD among seven cultivars ranged from 785 to 826 g/kg when harvested in July, and from 821 to 854 g/kg when harvested in August (Item B, Table 11–5). Forage concentrations of NDF and ADF also were similar among these cultivars. Nitrogen fertilization generally increased DMD (Item C, Table 11–5) and decreased the fiber fractions.

Soluble Carbohydrates

Although soluble carbohydrate data are extremely limited, those available indicate that large differences can occur among cuttings and among years. Smaller but important differences may occur among cultivars (Item B, Table 11–5).

Table 11–5. Dry matter disappearance (DMD) fiber fractions and soluble carbohydrates (CHO) concentrations in tall fescue when harvested for hay or silage.

Location†	Forage‡	Fescue cultivar	Management: Season	Management: General	Management: Fert.	DMD	NDF§	ADF§	CHO	References
					kg/ha	g/kg				
A. Tall fescue vs. other cool-season grasses										
WA	TF	Alta		Anthesis		532				Sosulski and Patterson, 1961
	BG					566				
	OG					619				
MN	TF	KY-31		2 cut		611	579			Marten and Hovin, 1980
	OG					614	582			
	RC					557	568			
	SB					589	564			
	TF	KY-31		3 cut		654	552			
	OG					669	551			
	RG					617	548			
	SB					665	549			
	TF	KY-31		4 cut		691	525			
	OG					696	521			
	RC					687	491			
	SB					698	501			
VA	TF	KY-31	Summer	Green-chop		548	691	416	97	Rayburn et al., 1980
	OG					570	698	446	84	
TX	TF	Fawn	Spring	Irrigation		566				Eck et al., 1981
	OG		Summer			615				
PA	TF	KY-31	Summer		Low P	615				Morris et al., 1982
					High P	616				
	OG				Low P	600				
					High P	603				
MN	TF	KY-31	All			671	596			Sheaffer and Marten, 1986
	RC					643	603			
	SB					682	577			
	BG					634	590			
	OG					667	582			
WV	TF	Kenhy	Spring			558	723	392		Barker et al., 1988

Location†	Forage‡	Fescue cultivar	Management: Season	Management: General	Management: Fert.	DMD	NDF§	ADF§	CHO	References
					kg/ha	g/kg				
			Fall			606	616	335		
	OG		Spring			512	715	415		
			Fall			511	681	384		
WV	TF	Kenhy	Spring			632		388		Prigge et al., 1999
	OG					617		411		
	TF	Kenhy	Fall			598		358		
	OG					597		370		
<u>B. Among tall fescue cultivars</u>										
KY	TF	KY-31					604	309		Ghorbani et al., 1991
		Kenhy					599	312		
		Johnstone					601	304		
ID	TF	KY-31	July			824¶	517	266	180	Burns et al., 2001
		Kenhy				826	520	266	166	
		HiMag				787	528	278	167	
		Barcel				818	543	287	149	
		Stargrazer				803	532	274	177	
		MO-96				785	530	275	177	
		Mozark				789	537	280	159	
		KY-31	August			835	528	253	85	
		Kenhy				854	519	248	85	
		HiMag				830	522	253	81	
		Barcel				853	526	257	76	
		Stargrazer				844	523	253	80	
		MO-96				830	530	255	72	
		Mozark				821	543	261	72	
<u>C. Nitrogen fertilization</u>										
WV	TF	KY-31	Initial growth		0 N		652	336	88	Reid and Jung, 1965
					56 N		613	325	49	
					168 N		627	328	17	
					504 N		596	311	33	

Table continued.

Table 11–5. Continued.

Location†	Forage‡	Fescue cultivar	Management: Season	General	Fert.	DMD	NDF§	ADF§	CHO	References
					kg/ha	g/kg				
			Regrowth		0 N		651	365	117	
					56 N		604	324	110	
					168 N		586	317	105	
					504 N		588	310	88	
TN	TF	KY-31			0 N		442		158	Hannaway and Reynolds, 1979
					112 N		415		169	
TX	TF	Fawn	Spring	Irrigated	0 N	576				Eck et al., 1981
			Summer		68 N	588				
					336 N	598				
					504 N	597				
					672 N	591				
D. Other managements										
CN	TF	KY-31	Cut 1	Long day		677	559	296		Allinson, 1971
		Kenwell		Short day		694	537	291		
			Cut 2	Long day		658	591			
				Short day		646	574			
IN	TF	KY-31	Diurnal	0600					215	Lechtenburg et al., 1972
				1200					233	
				1800					245	
				2400					232	
GA	TF	KY-31	Cool			775			153	Smith, 1977
			Hot			705			93	
KY	TF	KY-31	21 Apr.	−GR		639	340			Robb et al., 1982
			31 May	+GR		621	352			
			21 Apr.	−GR		698	399			
			15 July	+GR		673	385			
			21 Apr.	−GR		638	370			
			18 Aug.	+GR		677	389			
			7 June	−GR		625	299			
			14 July	+GR		636	322			

Location†	Forage‡	Fescue cultivar	Management Season	General	Fert.	DMD	NDF§	ADF§	CHO	References
					kg/ha	g/kg				
			7 June	−GR		659	351			
			18 Aug.	+GR		566	354			
PA	TF	KY-31	13/10	Green-				348	169	Fales, 1986
			20/18	house				427	208	
			30/27	study				501	235	
MN	TF	KY-31	April	−GR#		669	616			Sheaffer and Marten, 1986
				+GR		677	546			
TN	TF	KY-31	April	−GR		501	669			Reynolds et al., 1993
			July	+GR		540	648			
KY	TF	KY-31	Pre-	PM/G§§		470	693			Collins et al., 1995
			Storage	PS/G		464	688			
				T/G		462	684			
				T/I		460	699			
			Storage	PM/G		440	723			
				PS/G		461	730			
				T/G		428	721			
				T/I		467	730			
KY	TF	KY-31¶¶	Spring	Veg			687	344		Fieser and Vanzant, 2004
				Boot			739	379		
			Summer	Heading			738	423		
				Seeded			768	432		

† State where data were collected.

‡ TF = tall fescue; OG = orchardgrass; RC = reed canarygrass; SB = smooth bromegrass; KG = Kentucky bluegrass.

§ NDF = neutral detergent fiber; ADF = acid detergent fiber.

¶ Values are in vitro true dry matter disappearance.

GR = growth regulator.

§§ PM/G = plastic mesh warp stored on ground; PS/G = plastic solid warp stored on ground; T/G = twine tied stored on ground; T/I = twine tied stored indoors.

¶¶ Cultivar name not provided but assumed ‘Kentucky-31’.

Further, cool environmental conditions favored soluble carbohydrate buildup in the plant and tall fescue showed diurnal variation with soluble carbohydrates increasing from morning through 1800 h (Item D, Table 11–5).

Autumn-Stockpiled Forage

Accumulated or stockpiled forage is permitted to grow and develop during the growing season without utilization to provide feed during a subsequent season anticipated to have limited growth; specifically, it refers to late summer growth stockpiled for fall and winter utilization. This process is also referred to in the literature as autumn-saved forage.

Crude Protein

The concentration of CP in tall fescue tissue was less than in orchardgrass or Kentucky bluegrass, regardless of sampling time during the winter following an August start of forage accumulation (Item A, Table 11–6). For all the grass species studied, green tissue was greater in CP concentration than brown (dead) tissue. This trend was observed in stockpiled forage in Maryland, Kentucky, Virginia, and North Carolina. Values observed for the green tissue generally would be adequate to support moderate performance of most nonlactating ruminants during the wintering period (National Research Council, 1996).

Increased N application also increased CP concentrations in the forage (Item B, Table 11–6). Delaying N application from June to September increased CP concentrations sampled in December. An early July date to initiate accumulation resulted in rather low CP concentrations (74 g/kg) in December, and N applications of 200 kg/ha increased CP concentrations by only 22 to 96 g/kg. Delaying harvest until February generally reduced CP concentrations, but only slightly.

When tall fescue was clipped instead of stockpiled during late summer, CP concentrations averaged 154 g/kg, compared with lower concentrations when forage was stockpiled from June, July, or September and sampled in August, September, and November, respectively (Item C, Table 11–6). Generally, delaying the time to begin forage accumulation from June to September increased the CP concentration of the subsequent stockpile when sampled in mid-winter (Item C, Table 11–6). A noted exception was reported by Rayburn et al. (1980): CP concentrations changed little when forage was accumulated from June, July, or August and sampled in December (101 to 108 g/kg). A September accumulation sampled in December gave greater CP concentrations 1 yr (132 g/kg), but concentrations were similar to the longer accumulation periods in a second year (106 g/kg). Low CP concentrations from shorter accumulation periods were attributed to weathering associated with early frost damage and higher than normal fall precipitation.

Delaying sampling in the fall, regardless of the time when the stockpile was initiated, also reduced the CP concentrations measured. In North Carolina, the lowest CP concentration generally occurred by mid December to January, with concentrations increasing somewhat by early February and March. This increase was attributed to new growth of tall fescue, which can sometimes occur by February in that region.

Dry Matter Disappearance and Fiber Fractions

Delaying the sampling of accumulated tall fescue and orchardgrass from October to December reduced TDD and increased NDF in both species (Item A,

Table 11–6. Crude protein concentration of tall fescue when stockpiled for late fall and winter utilization.

Location†	Forage‡	Fescue cultivar	Date Accum.	Date Sampled	Fert.	Tissue	Crude Protein	References
					kg/ha		g/kg	
A. Tall fescue vs. other cool-season grasses								
KY	TF	KY-31	15 Aug.	1 Oct.		Green	140	Taylor and Templeton, 1976
				1 Nov.			116	
				1 Dec.			111	
				8 Feb.			127	
				2 Mar.			156	
	BG		15 Aug.	1 Oct.			179	
				1 Nov.			155	
				1 Dec.			146	
				8 Feb.			152	
				2 Mar.			174	
	TF	KY-31	15 Aug.	1 Oct.		Brown	69	
				1 Nov.			66	
				1 Dec.			77	
				8 Feb.			86	
				2 Mar.			88	
	BG		15 Aug.	1 Oct.			93	
				1 Nov.			98	
				1 Dec.			99	
				8 Feb.			105	
				2 Mar.			105	
MD	TF	KY-31	10 Sept.	10 Oct.			167	Archer and Decker, 1977a,b
				17 Nov.			150	
				24 Dec.			137	
	OG		10 Sept.	10 Oct.			173	
				17 Nov.			160	
				24 Dec.			152	
VA	TF	KY-31		Nov.		Green	123	Sheehan et al., 1985
						Dead	76	
	OG					Green	138	
						Dead	95	
	TF	KY-31		Dec.		Green	118	
						Dead	75	
	OG					Green	129	
						Dead	81	
B. Nitrogen fertilization								
VA	TF	KY-31	June	Dec.	0 N		84	Rayburn et al., 1979
			July	Dec.			87	
			Aug.	Dec.			94	
			Sept.	Dec.			103	
			June	Dec.	112 N		82	
			July	Dec.			87	
			Aug.	Dec.			88	
			Sept.	Dec.			103	
			June	Dec.			95	
			July	Dec	112 N		93	
			Aug.	Dec.			94	
			Sept.	Dec.			103	
			June	Dec.			98	
			July	Dec.			108	
			Aug.	Dec	112 N		107	
			Sept.	Dec.			110	
			June	Dec.			111	

Table continued.

Table 11–6. Continued.

Location†	Forage‡	Fescue cultivar	Date Accum.	Date Sampled	Fert.	Tissue	Crude Protein	References
					kg/ha		g/kg	
			July	Dec.			129	
			Aug.	Dec.			140	
			Sept.	Dec.	112 N		147	
WV	TF	KY-31	Early	Dec.	0 N		74	Collins and Balasko, 1981
			July		60 N		76	
					120 N		80	
					180 N		96	
				Feb.	0 N		71	
					60 N		72	
					120 N		84	
					180 N		102	
WV	TF	KY-31	Early	Feb.	0 N		93	Collins and Balasko, 1981
			Sept.		75 N		93	
					150 N		111	
					225 N		129	
MO	TF	KY-31	Aug.		0 N		157	Gerish et al., 1994
					45 N		161	
					90 N		165	
					135 N		169	
C. Other management								
VA	TF	KY-31	15 Aug.	1 Sept.			179	Brown et al., 1963
				9 Sept.			151	
				2 Oct.			121	
				16 Oct.			106	
				31 Oct.			92	
				15 Nov.			105	
IA	TF	KY-31		7 Oct.			189	Bryan et al., 1970
				7 Nov.			161	
				28 Nov.			120	
	RC			7 Oct.			222	
				7 Nov.			146	
				28 Nov.			174	
TN	TF	KY-31	Clipped	Fall			154	Fribourg and Loveland, 1978b
			June	Sept.			115	
			July	Oct.			108	
			Sept.	Dec.			91	Rayburn et al., 1979
VA	TF	KY-31	June	Dec.			94	
			July				100	
			Aug.				105	
			Sept.				113	
VA	TF	KY-31	June	Dec.			101	Rayburn et al., 1980
			July				107	
			Aug.				103	
			Sept.				119	
TN	TF	KY-31	1 July	Jan.			52	Fribourg and Bell, 1984
			1 Aug.				58	
			1 Sept.				120	
NC	TF	KY-31	1 June	15 Nov.			126	Burns and Chamblee, 2000a
			1 July				127	
			1 Aug.				128	
			1 Sept.				128	

Table continued.

Table 11–6. Continued.

Location†	Forage‡	Fescue cultivar	Date Accum.	Date Sampled	Fert.	Tissue	Crude Protein	References
					kg/ha		g/kg	
NC	TF	KY-31	1 June	15 Oct.			147	Burns and Chamblee, 2002
				13 Nov.			126	
				10 Dec.			106	
				8 Jan.			106	
				5 Feb.			115	
				5 Mar.			131	
			1 July	15 Oct.			156	
				13 Nov.			127	
				10 Dec.			110	
				8 Jan.			112	
				5 Feb.			121	
				5 Mar.			134	
			1 Aug.	15 Oct.			152	
				18 Nov.			128	
				10 Dec.			106	
				8 Jan.			115	
				5 Feb.			121	
				5 Mar.			134	
			1 Sept.	15 Oct.			162	
				13 Nov.			128	
				10 Dec.			113	
				8 Jan.			96	
				5 Feb.			110	
				5 Mar.			140	
NC	TF	Jesup (Max Q)	15 Aug.	15 Nov.		Whole	125	Burns et al., 2006
						Leaf	151	
						Stem	82	
						Dead	100	
				15 Dec.		Whole	117	
						Leaf	151	
						Stem	87	
						Dead	96	
				15 Jan.		Whole	104	
						Leaf	138	
						Stem	91	
						Dead	87	
				15 Feb.		Whole	118	
						Leaf	173	
						Stem	106	
						Dead	94	
NC	TF	KY-31		3 Dec.		Whole	153	Poore et al., 2006
						Green	202	
						Brown	107	
				16 Dec.		Whole	157	
						Green	172	
						Brown	98	
				30 Dec.		Whole	144	
						Green	161	
						Brown	89	
				13 Jan.		Whole	141	
						Green	158	
						Brown	85	
				27 Jan.		Whole	141	

Table continued.

Table 11–6. Continued.

Location†	Forage‡	Fescue cultivar	Date Accum.	Date Sampled	Fert.	Tissue	Crude Protein	References
					kg/ha		g/kg	
						Green	174	
						Brown	93	
				10 Feb.		Whole	164	
						Green	204	
						Brown	103	
				24 Feb.		Whole	182	
						Green	201	
						Brown	88	

† State where data were collected.

‡ TF = tall fescue; BG = Kentucky bluegrass; OG = orchardgrass.

Table 11–7). In general, TDD values were slightly greater and NDF slightly less for tall fescue than for orchardgrass.

Examining the green and the brown tissues showed that green tissue had greater TDD than brown tissue regardless of forage species, dates of accumulation, and sampling dates. Second, both tall fescue and orchardgrass changed similarly in DMD and NDF, with the green tissue from tall fescue slightly greater in TDD and with less NDF when forages were accumulated in Maryland. These relationships were less consistent when the two species were stockpiled and compared in Virginia.

The application of 67–84 kg N/ha at time of accumulation generally increased DMD compared with no N fertilizer, but greater rates showed little additional effect in either December or February (Item B, Table 11–7). Applying N, P, and K as a complete fertilizer in August did not alter DMD of the forage in January.

Tall fescue that was clipped during autumn had greater DMD than forage that was accumulated from June or July and sampled in August and September (Item C, Table 11–7). Forage accumulated from September and sampled in November had DMD that was similar to that in the clipped treatment. In general, delaying the date when accumulation was initiated increased DMD and decreased NDF of the forage when sampled in November, December, or January.

Within an accumulation treatment, whether initiated in June, July, August, or September, DMD generally increased from October to November, but showed a large decrease by the December sampling. Both NDF and ADF showed concurrent increases by the December sampling. Increases in DMD and decreases in NDF and ADF can occur in March with the onset of new growth.

Soluble Carbohydrates

Green tissue of tall fescue, orchardgrass, and Kentucky bluegrass had appreciably greater soluble carbohydrate concentrations than dead tissue from the same plants (Item A, Table 11–7). Generally, tall fescue retained its soluble carbohydrate status into the fall and winter better than either orchardgrass or Kentucky bluegrass.

Table 11–7. Dry matter disappearance (DMD), fiber fractions, and soluble carbohydrates (CHO) of stockpiled tall fescue.

Location†	Forage‡	Fescue cultivar	Date		Fert.	Tissue	DMD	NDF§	ADF§	CHO	References
			Accum.	Sampled							
					kg/ha		g/kg				
A. Tall fescue vs. other cool-season grasses											
KY	TF	KY-31	15 Aug.	1 Oct.		Green				130	Taylor and Templeton, 1976
						Dead				11	
				1 Nov.		Green				186	
						Dead				14	
				1 Dec.		Green				218	
						Dead				23	
				1 Feb.		Green				205	
						Dead				21	
				2 Mar.		Green				177	
						Dead				13	
	BG		15 Aug.	1 Oct.		Green				128	
						Dead				8	
				1 Nov.		Green				155	
						Dead				12	
				1 Dec.		Green				194	
						Dead				16	
				1 Feb.		Green				167	
						Dead				12	
				2 Mar.		Green				158	
						Dead				10	
MD	TF	KY-31	10 Sept.	10 Oct.			874¶	507			Archer and Decker, 1977 a,b
				17 Nov.			826	535			
				24 Dec.			790	542			
	OG		10 Sept.	10 Oct.			864	514			
				17 Nov.			779	542			
				24 Dec.			730	554			
	TF	KY-31	10 Sept.	10 Oct.		Green	884				

Table continued.

Table 11–7. Continued.

		Fescue	Date								
Location†	Forage‡	cultivar	Accum.	Sampled	Fert.	Tissue	DMD	NDF§	ADF§	CHO	References
					kg/ha		g/kg				
						Dead	657				
				17 Nov.		Green	901				
						Dead	670				
				24 Dec.		Green	870				
						Dead	682				
	OG		10 Sept.	10 Oct.		Green	885				
						Dead	693				
				17 Nov.		Green	886				
						Dead	668				
				24 Dec.		Green	830				
						Dead	647				
VA	TF	KY-31		Nov.		Green	689		272	213	Sheehan et al., 1985
						Dead	475		453	31	
	OG					Green	714		241	233	
						Dead	519		412	39	
	TF	KY-31		Dec.		Green	719		279	219	
						Dead	481		357	44	
	OG					Green	702		266	189	
						Dead	544		368	40	
B. Nitrogen fertilization											
WV	TF	KY-31	Aug.	Jan.	0		504			61	Balasko, 1977
					NPK		509			72	
GA	TF	KY-31	Sept.	30 d	56 N	Green	746				Beaty et al., 1978
						Dead	437				
			May		240 N	Green	755				
						Dead	419				
VA	TF	KY-31	June	Dec.	0 N					141	Rayburn et al., 1979
			July	Dec.						173	
			Aug.	Dec.						183	
			Sept.	Dec.						181	

Location†	Forage‡	Fescue cultivar	Date Accum.	Date Sampled	Fert.	Tissue	DMD	NDF§	ADF§	CHO	References
					kg/ha		g/kg				
			June	Dec.	112 N					133	
			July	Dec.						170	
			Aug.	Dec.						157	
			Sept.	Dec.						198	
			June	Dec.						149	
			July	Dec.	112 N					172	
			Aug.	Dec.						202	
			Sept.	Dec.						212	
			June	Dec.						178	
			July	Dec.						197	
			Aug.	Dec.	112 N					227	
			Sept.	Dec.						266	
			June	Dec.						185	
			July	•Dec.						215	
			Aug.	Dec.						262	
			Sept.	Dec.	112 N					293	
WV	TF	KY-31	Early	Dec.	0 N		477			63	Collins and Balasko, 1981
			July		60 N		473			75	
					120 N		450			70	
					180 N		475			64	
				Feb.	0 N		427			41	
					60 N		417			41	
					120 N		434			43	
					180 N		385			37	
WV	TF	KY-31		Feb.	0 N		581			50	Collins and Balasko, 1981
					75 N		620			73	
					150 N		627			81	
					225 N		627			80	
<u>C. Other managements</u>											
TN	TF	KY-31	Clipped				626				Fribourg and Loveland, 1978b
			June	Sept.			494				

Table continued.

Table 11–7. Continued.

Location†	Forage‡	Fescue cultivar	Date: Accum.	Date: Sampled	Fert.	Tissue	DMD	NDF§	ADF§	CHO	References
					kg/ha		g/kg				
			July	Oct.			591				
			Sept.	Dec.			622				
TN	TF	KY-31	Sept.					470		110	Hannaway and Reynolds, 1979
			Oct.					440		190	
			Nov.					270		250	
			Dec.					340		150	
			Feb.					360		210	
VA	TF	KY-31	June	Dec.			623	570	323	176	Rayburn et al., 1980
			July				667	547	312	198	
			Aug.				674	521	302	218	
			Sept.				669	492	280	221	
TN	TF	KY-31	1 July	Jan.				720			Fribourg and Bell, 1984
			1 Aug.					640			
			1 Sept.					660			
NC	TF	KY-31	1 June	15 Nov.			620	543		89	Burns and Chamblee, 2000b, 2002
			1 July				640	523		91	
			1 Aug.				670	496		104	
			1 Sept.				711	463		127	
NC	TF	KY-31	1 June	15 Oct.			570	538	310	89	Burns and Chamblee, 2000b, 2002
				13 Nov.			620	543	313		
				10 Dec.			595	540	306	156	
				8 Jan.			490	616	343		
				5 Feb.			495	636	359		
				5 Mar.			529	633	362		
			1 July	15 Oct.			624	530	277	90	
				13 Nov.			640	523	316		
				10 Dec.			629	535	287	145	
				8 Jan.			524	606	335		
				5 Feb.			529	624	352		
				5 Mar.			564	616	350		
			1 Aug.	15 Oct.			669	512	268	104	

Location†	Forage‡	Fescue cultivar	Date Accum.	Date Sampled	Fert.	Tissue	DMD	NDF§	ADF§	CHO	References
					kg/ha		g/kg				
				13 Nov.			670	496	283		
				10 Dec.			639	531	277	140	
				8 Jan.			572	604	323		
				5 Feb.			575	611	337		
				5 Mar.			587	615	342		
			1 Sept.	15 Oct.			717	475	310	127	
				13 Nov.			711	463	273		
				10 Dec.			699	497	256	190	
				8 Jan.			600	577	308		
				5 Feb.			612	594	333		
				5 Mar.			623	596	333		
NC	TF	Jesup (MaxQ)	15 Aug.	15 Nov.		Whole	763¶	522	273	220	Burns et al., 2006
						Leaf	848	441	231	271	
						Stem	875	429	211	448	
						Dead	558	712	376	22	
				15 Dec.		Whole	738	533	277	211	
						Leaf	857	428	217	283	
						Stem	880	410	198	448	
						Dead	559	708	376	33	
				15 Jan.		Whole	715	565	291	189	
						Leaf	872	414	205	312	
						Stem	880	414	195	423	
						Dead	571	713	375	42	
				15 Feb.		Whole	675	620	317	107	
						Leaf	886	430	205	227	
						Stem	883	448	204	337	
						Dead	545	740	389	16	
NC	TF	KY-31		3 Dec.		Whole	781 ¶	560	262		Poore et al., 2006
						Green	869	501	221		
						Brown	639	700	346		
				16 Dec.		Whole	813	519	259		

Table continued.

Table 11–7. Continued.

Location†	Forage‡	Fescue cultivar	Date Accum.	Date Sampled	Fert.	Tissue	DMD	NDF§	ADF§	CHO	References
					kg/ha		g/kg				
						Green	886	478	222		
						Brown	660	684	349		
				30 Dec.		Whole	764	569	288		
						Green	884	482	222		
						Brown	661	692	352		
				13 Jan.		Whole	754	587	294		
						Green	877	519	332		
						Brown	620	731	373		
				27 Jan.		Whole	738	606	309		
						Green	893	515	227		
						Brown	598	738	374		
				10 Feb.		Whole	762	583	334		
						Green	903	538	230		
						Brown	643	729	372		
				24 Feb.		Whole	826	583	266		
						Green	906	520	229		
						Brown	626	748	380		

† State where data were collected.

‡ TF = tall fescue; BG = Kentucky bluegrass; OG = orchardgrass.

§ NDF = neutral detergent fiber; ADF = acid detergent fiber.

¶ In vitro true dry matter disappearance.

Nitrogen fertilization of tall fescue at modest application rates generally increased soluble carbohydrates in December and January. Stockpiles that began accumulation no earlier than September generally had greater soluble carbohydrate concentrations in the fall and winter than those accumulated over a longer period of time.

Proportion of Green and Dead Tissue, and Nutritive Value

The proportion of the accumulated stockpile that remains as green tissue during the fall and winter season has an important impact on animal daily response. It is well established that grazing animals select for green leaf tissue and against brown or dead tissue (Hodgson, 1981). As the winter season progresses, stockpiled tall fescue generally declines in the proportion of green tissue and increases in the proportion of brown or dead tissue (Taylor and Templeton, 1976; Archer and Decker, 1977b). Further, the proportion of dead tissue can vary widely from year to year depending on the length of the accumulation period and weather conditions during accumulation. Burns and Chamblee (2000a) showed that when tall fescue was stockpiled monthly in the Piedmont of North Carolina from June to September, the proportion of dead tissue in the November stockpiled forage ranged from 54 to 70% in one year and from 61 to 77% in another year. However, all accumulated forage in December of both years, regardless of accumulation date, had similar proportions of green tissue (26%). This type of variation was reported also by Beaty et al. (1978) in the mountains of Georgia.

Proportion of Green and Dead Tissue

Selecting an August closing date and examining the stockpiled herbage revealed that as the fall and winter progressed, the DMD and CP concentrations declined while NDF increased (Burns and Chamblee, 2000b). Associated with these changes was a decline in green tissue and an increase in dead tissue. Upon examination of the stockpiled forage it was noted that the green tissue was greater in DMD (708 g/kg) and lesser in NDF (489 g/kg), whereas the dead tissue had reduced DMD (401 g/kg) and increased NDF (700 g/kg) (Burns and Chamblee, 2002). Further, neither the green nor the dead tissue changed much in composition during the entire fall and winter season. Consequently, the decline in the nutritive value of the stockpile was attributed mainly to the shift in the proportions of green and dead tissues. The relationship between DMD and the proportion of dead tissue showed a decline in DMD ranging from 26 to 55 g/kg, depending on the year, for each increase of 10% units in dead tissue (Burns and Chamblee, 2000b). Moreover, Archer and Decker (1977b) proposed that dead tissue resulting from normal senescence that occurs during accumulation may influence nutritive value differently than dead tissue from cold damage. This was verified by Burns and Chamblee (2000b), who showed tissue that died during accumulation had low DMD in October and changed little during the fall and winter sampling period. They also showed that stockpiled forage that had little dead tissue in October (little senescence) had greater DMD, and, as the dead proportion increased during the winter from cold damage, the DMD remained high. These same trends also were noted for Jesup and MaxQ tall fescues when stockpiling began 15 August and it was sampled from mid November through mid December (Burns et al., 2006b).

The proportion of the tall fescue stockpile that can be retained as green tissue appears to be influenced by the length of the accumulation period and by the severity of the weather during both accumulation and utilization phases. Shorter, late-summer accumulation periods and utilization by mid December improved the nutritive value of stockpiled tall fescue and made the forage a more suitable feed for either growing or producing animals. Longer summer accumulation periods resulted in greater dry matter yields, but the stockpile was least in nutritive value; delaying utilization until December resulted in forage that was suitable only for maintenance. Within a systems context, both management strategies may be appropriate, and the projected feed demand for each animal class can be used to develop a mix of pasture managements appropriate for a particular production system.

Palatability

When greater daily animal responses are desired, it is critically important that the feed offered be high enough in nutritive value and consumed daily in sufficient quantities to provide the desired level of gain. In both grazing and conserved forage feeding systems, a key objective is to use plants with characteristics that will support the target feed intake and gain. In the early literature, tall fescue frequently was categorized as lacking palatability (Cowan, 1956) and being low in nutritive value (Crowder, 1955) or of low quality (Lassiter et al., 1956; Jacobson et al., 1957). An assessment of tall fescue strains showed that palatability differences were present, but there was little relationship between the quantity of forage available and its palatability (Buckner and Burrus, 1962). In a subsequent study, Craigmiles et al. (1964) reported a significant correlation between palatability and leaf size and texture (broad vs. fine leaf). Generally, they noted that broad and thick, coarse, leafy plants were preferred, and preference was attributed to forage that was more succulent and tender. In further evaluation with cattle, it was shown that the selected germplasm was more palatable than the naturalized or commercial cultivars available at that time (Buckner, 1960). Although tall fescue populations under evaluation were segregating for characteristics such as CP, silica, and total sugars, cattle showed no selection (at least with the preference procedures used) of one germplasm over another (Buckner et al., 1969). The extent to which the endophyte was present in the forages evaluated and the degree to which it might have played a role in animal evaluations remains obscure. Consequently, much of the early work addressing the topic of palatability of tall fescue lacks the data necessary for an appropriate interpretation and does not warrant further consideration.

More recent evaluation using E− tall fescue cultivars or germplasms ['Barcel'; C1 and HiMag (a first generation and a second generation selection, respectively, for increased Mg and Ca; Mayland and Sleper, 1993); Kenhy; KY-31; 'Missouri 96'; 'Mozark'; and Stargrazer] demonstrated that heifers grazed these entries selectively, giving a ranking of: Kenhy > KY-31 > HiMag = Barcel = C1 = Stargrazer > Missouri 96 = Mozark (Shewmaker et al., 1997). These results indicated palatability differences among the eight entries tested. To remove possible effects of morphological differences among these entries on ruminant preference (Krueger et al., 1974), the same plots used in the study by Shewmaker et al. (1997) were cut and harvested as hay. The hay was reduced into 7- to 13-cm lengths and fed in palatability trials in confinement using sheep and goats. In general, animals ranked the palatability similarly among the entries in confinement and grazing. Selection among the entries was attributed, in part, to differences in soluble carbohydrates and CP (Burns et al., 2001).

The potential presence of the toxic endophyte in tall fescue complicates the discussion of tall fescue palatability relative to other cool-season grasses. It is necessary to keep the endophyte status in mind to evaluate tall fescue properly, in light of the novel endophytes with reduced production of alkaloids that are being developed and inserted into improved tall fescue cultivars. Such positive changes may extend the utility of tall fescue beyond the north–south transition zone of the United States and make it a cool-season species used more widely in production systems throughout the world where it currently is, or might be, adapted.

Nutritive Value and Animal Responses—A Paradox

Tall fescue has anatomical characteristics and nutritive value similar to those of other perennial C_3 grasses. Its consumption by ruminants should result in daily intake of dry matter comparable to that of any perennial cool-season grass containing adequate nutrients that can be converted readily to support very acceptable daily animal responses. An assessment of the literature, however, provides a striking paradox, with daily animal responses ranging from those expected, based on laboratory estimates of the nutritive value of tall fescue, to greatly suppressed performance that does not reflect the measured nutritive value. This discrepancy has been attributed to the occurrence of the fungal endophyte *N. coenophialum* in tall fescue. The tall fescue–*N. coenophialum* symbiont produces alkaloid compounds that can have negative impacts on animal physiology and, hence, animal behavior, including daily performance, but remain separate from changes in nutritive value. In production settings this paradox is complicated by the influence of the endophyte–alkaloid association affecting plant and animal physiologies and resulting in a wide range of animal daily responses that may have little to no bearing on the measured nutritive value of tall fescue. Interacting plant factors and animal factors contribute to this paradox when animals are consuming tall fescue and are paramount in producing the ultimate in forage evaluation, the animal daily responses. Delineated below are some of the major plant and animal factors, along with associated examples of their interactions, which form the basis for the paradox.

Plant Factors

The major plant-related factors that contribute to variation in data found in the literature and often attributed to nutritive value range from imposed grazing management strategies to plant– endophyte symbiosis to weather influences (see Chapter 4, Belesky and West, 2009, this publication) are listed below.

1. Tall fescue has optimum daily maximum growing conditions only during the cooler portions (18–24°C) of the growing season, yet it is frequently utilized to some extent during 12 mo/year in the north–south transition zone. Expectations, although unfounded, frequently exist of continued good production and high nutritive value throughout the year. This is attributed, in part, to its tendency to remain green year-round except during periods of high summer temperatures (>32°C) and water deficit stress.

2. Within a pasture, some plants may contain the toxic endophyte that imparts plant tolerances to a wide range of stresses, thereby favoring plant survival, but has no influence on nutritive value. Thus, the proportion of infected plants may increase in older swards and, with time, dominate the forage stand.
3. Among pastures, tall fescue stands can vary widely in the proportion of E+ plants, ranging from zero infection to 100% infection, providing the grazing animal with a wide range of choices in alkaloid concentrations in its diet but with little difference in nutritive value.
4. The endophyte activity in infected plants increases as ambient air temperatures climb above 20°C in late spring and with the onset of summer. This shift is more likely to affect animal responses negatively.
5. The occurrence of the endophyte generally is greater in the lower portion of the stems than in the leaves, having important implications in grazing utilization strategies.
6. The literature often lacks documentation of the presence of the endophyte or the endophyte infestation frequency, if present, in the tall fescue stand being evaluated and the subsequent alkaloid concentrations of the associated forage. Further, the name of the cultivar being evaluated sometimes is omitted, with reference made only to tall fescue or "fescue grass".

Animal Factors

The major animal-related aspects of tall fescue utilization that contribute to variation and contradictory information in the literature that are attributed to nutritive value, are associated with animal responses to environmental stresses and to alkaloid type and concentrations. The major animal factors are listed below.

1. Animal physiology is sensitive to certain types and concentrations of specific alkaloids produced and present in tall fescue forage.
2. As ambient air temperature rises above 27°C and relative humidity increases in late spring with the onset of summer, the animal experiences an increase in environmental stress. Environmental stress and stress that is associated with alkaloid toxicity further aggravate toxicosis signs and reduce dry matter intake and growth rate.
3. Within and among breeds and species, animals have different tolerances and exhibit varying degrees of physiological stress under similar temperature and relative humidity and have different physiological tolerances to the presence, type, and concentrations of specific alkaloids in tall fescue.

Plant-Animal Factors

The plant and animal factors listed above can interact to modify the observed toxicosis, while in other instances they may act independently. Some examples of plant and animal interactions to generate the basis of the paradox in a production setting are noted below.

1. Animal foraging behavior varies among individual animals, but in general they select green leaves when given the opportunity; however, selectivity declines as forage "on offer" declines. As forage variability declines, animals graze deeper into the canopy, thereby increasing the likelihood of consuming more of the basal stems. Consequently, in tall fescue pastures infested with the toxic endophyte, animals shift from consuming a diet greater in nutritive value with less occurrence of endophyte (diet with

greater proportion of leaf) to a diet that is of lesser nutritive value and greater occurrence of endophyte (diet with a greater proportion of stem and stem bases).

2. As ambient air temperatures rise above 27°C and relative humidity increases, animals normally experience greater physiological stress, but concurrent with this stress is an increase in endophyte concentrations and a reduction in nutritive value of tall fescue forage. This increases the alkaloids but reduces the nutrients consumed by the animal, compounding the effect. The degree of the stress response, however, remains specific to the individual animal and is complicated by genetic inheritance and hybrid crosses.
3. Dilution of E+ tall fescue by weedy species or by interseeding with other forages, such as legumes or endophyte-free grasses, provides a pasture with reduced overall endophyte infection. Animals will graze selectively, however, and selectivity will remain animal specific; thus alkaloid consumption will be highly variable. This will change, as will nutritive value, as available herbage mass shifts from the most preferred to the residual species and plant parts.
4. Animal response data frequently are reported in the literature as means over a period of time, often designated as either spring or fall grazing, and can be extremely misleading. A spring designation, for example, may represent a grazing period beginning in late March and continuing through mid-to-late July. This period encompasses the transition from a cool (<27°C) spring environment to a hot and humid (>31°C) summer environment. During this period, if a tall fescue pasture is infested with a toxic endophyte, endophyte levels, and hence alkaloid concentrations, will be highly variable and interacting with the environment. Also during this period, grazing behavior and physiological stresses in the animal vary and interact with the environment and with the diet, including its nutritive value. The many plant, animal, and environmental factors all have variable influences on animal daily responses. Consequently, animal responses during the period reported can be sufficiently confounded by the presence of the endophyte such that interpretation of the resulting data is problematic and may be of little utility.

The integration of the plant and animal factors with accurate predictions of their interactions, as well as endophyte status, frequently is lacking in the available literature. Often the reporting of data as means compresses the spring to summer transition period in forage utilization trials and presents a major interpretive challenge for the reader. Consequently, even though a substantial body of literature exists, special care must be exercised to interpret the utility of each of its components.

Conclusions

Early literature reporting research on the nutritive value and use of tall fescue by animals before the recognition of the existence of the fungal endophyte and the removal of the toxic products often contains animal responses that are difficult or impossible to interpret or reproduce. This permits the opportunity to select data that will support nearly any point of view regarding animal performance on tall fescue. Consequently, animal response data obtained during that earlier period are of historical interest but of limited use in estimating the value of tall fescue in production systems. From a historical perspective, the literature is valuable in detailing the discovery and significance of the toxic endophyte. Second, based on our present knowledge, studies in the literature that were not confounded can verify certain plant–animal responses and basic endophyte alkaloid and plant associations.

With the recent identification and successful insertion of known endophytes into current or new tall fescue cultivars, experiments now can be conducted to evaluate the nutritive value and quality of tall fescue forage without the confounding influence of toxins from the fungal endophyte. In such experiments the contribution of the nontoxic endophyte on the physiology of the plant, as related to growth and persistence, also can be assessed. Studies such as small plot yield and persistence trials, grazing evaluations, and animal stall trials need to be conducted with the improved tall fescue cultivars and with comparisons among other cool-season grasses. Combining yield, persistence, nutritive value, and quality estimates in these studies is urgently needed as opposed to focusing simply on any one entity. In addition, care needs to be exercised in these studies to include the type of treatments needed based on our previous 50 yr of experience.

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